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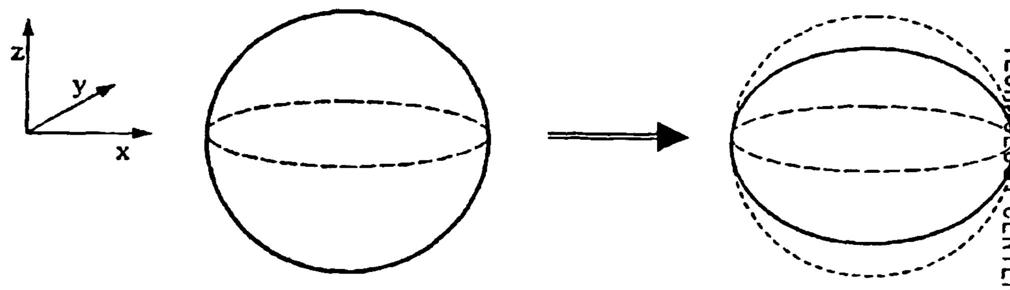
(54) Title: PROCESS FOR MANUFACTURING A POLYMER COMPENSATION LAYER FOR AN LCD, AND CONSTRUCTION OF AN LCD



(57) Abstract: This invention solves the technical problem of compensating for the angular dependence of the contrast in optical devices comprising liquid crystal displays (LC optical light shutters, which operate on the principle of electrically controlled optical birefringence), with the aid of a compensation layer exhibiting optically negative birefringence, which enables the angular compensation of the LC layer birefringence in the state in which the LC molecules are homeotropically aligned (typical optically positive birefringence). The process for the manufacture of the optically negatively birefringent compensation layer is devised on the controlled spontaneous deformation of the polymer molecules during the polymerization procedure. The manufacturing process is feasible by the employment of known and well-controllable technical procedures, and enables the mass production of compensation layers. The invention solves the problem of manufacturing a compensation layer exhibiting the required optically negative birefringence, as well as the construction/manufacturing of the optical light shutter, which utilizes such a compensation film.

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(54) Title: PROCESS FOR THE MANUFACTURING OF THE POLYMER COMPENSATION LAYER FOR LCD OPTICAL LIGHT SHUTTER AND THE CONSTRUCTION THEREOF

(57) Abstract: This invention solves the technical problem of compensating for the angular dependence of the contrast in optical devices comprising liquid crystal displays (LC optical light shutters, which operate on the principle of electrically controlled optical birefringence), with the aid of a compensation layer exhibiting optically negative birefringence, which enables the angular compensation of the LC layer birefringence in the state in which the LC molecules are homeotropically aligned (typical optically positive birefringence). The process for the manufacture of the optically negatively birefringent compensation layer is devised on the controlled spontaneous deformation of the polymer molecules during the polymerization procedure. The manufacturing process is feasible by the employment of known and well-controllable technical procedures, and enables the mass production of compensation layers. The invention solves the problem of manufacturing a compensation layer exhibiting the required optically negative birefringence, as well as the construction/manufacturing of the optical light shutter, which utilizes such a compensation film.

Process for the manufacturing of the polymer compensation layer for LCD optical light shutter and the construction thereof

The object of the present invention is a process for the manufacture of optically negatively birefringent compensation layers, based on the controlled spontaneous deformation of the polymer macromolecules during the polymerization process, as well as the construction of an optical light shutter utilizing such a compensation layer.

The technical field, dealing with this invention, is the compensating for the angular dependence of the intensity of the transmitted light in optical apparatus equipped with liquid crystal light shutters. In the following text, the liquid crystal shall be denominated LC (Liquid Crystal).

The technical problem, solved by this invention, is the enlargement of the viewing angle, and the compensation of the angular dependence of the transmitted light intensity in the liquid crystal shutter elements respectively, either in autonomous elements in LCD (Liquid Crystal Display), or as components of optical apparatus comprising liquid crystal filters. More precisely, there is involved the compensation of LC optical light shutters, which function on the principle of electrically controlled birefringence, and are employed for modulating the intensity of the incident light in protective/safety

devices, such as LCD protective filters in welding helmets, in optical systems of laser welding devices, and the like. The present invention enables the angular compensation of such a shutter in a typically closed state, in which the liquid crystal molecules are homeotropically aligned. This invention solves the problem of manufacturing a negatively birefringent compensation layer, which has the optical angle oriented perpendicularly with respect to the surface of the optical light shutter, that is parallel to the homeotropically oriented molecules, as well as the construction and the manufacture of a LC electro-optical shutter element, utilizing such a compensation layer.

The basic principles and natural laws, applied in the claimed process for the angular compensation of LC light shutters, which is the object of the present invention, are well-known and disclosed in several patents, such as Clerc *et al.* US 4,001,028; Yamamoto *et al.* US 4,984,874; Bos US 5,187,603 and the like. Hitherto, there have been developed several successful technical solutions for the manufacture of compensation layers for LCD optical shutters.

The first successful solution (#1) of the above mentioned technical problem was disclosed in 1989 by Uchida of the Tohoku University (Uchida *et al.* SID 89 Digest, p 378-381), and in 1991 by Clerc of the Stanley company (SID Digest 91 p 758-761; US 4,889,412; US 5,298,199). Both solutions were based on the two-dimensional mechanical deformation or stretching respectively, of certain thermoplastic polymer materials during the thermal cycling through the glass phase transition. A few years later, a functionally similar result was achieved by Eblen *et al.* from the Rockwell Company (SID 94 Digest p 245-248; US 5,196,953) with the use of multi-layer thin-film oxide filters exhibiting negatively birefrigent properties.

A new, technically highly interesting approach (#2) was developed by Harris and Cheng at the Akron University, USA, and somewhat later by Shin-Tson-Wu from the Hughes company, USA (J.Appl. Phys. 76, 10, 1994; SID Digest

94, p 923-926; US 5,344,916; US 5,580,950; US 5,480,964). They disclosed that by means of centrifugal deposition of a thin layer of preimidized polyimides the long molecular segments were preferably oriented in the plane of the deposited layer, resulting in strong negatively birefringent properties of such layers, which represent an inexpensive and technically relatively simple solution of the above described technical problem.

By all means, there also merit attention several technical solutions developed for computer terminals (#3) in companies, such as Nito Denko (Fujimura *et al.* SID Digest 91, p 739, SID Digest 92, p 397-400; US 5,245,456, ...), Sumitomo (Nakamura *et al.* US 5,061,042, ...) and (#4) Fuji Film (Mori *et al.*, US 5,559,618; Mori *et al.*, Display and Imaging 5, p 1 (96); Kamata *et al.*, US 5,646,703; Mori *et al.* US 5,583,679) and Akzo Nobel (Picken *et al.* US 5,382,648; US 5,525,265,...). The companies Nito and Sumitomo (#3) developed a multi-layer compensation film based on a one-dimensional deformation or stretching respectively; the Fuji company (#4) developed a polymeric discotic liquid crystal compensation sheet, the optical compensation properties of which could be altered with respect to the viewing/observation angle of the computer monitor; the Akzo Nobel company (#4) developed polymeric holesteric liquid crystal compensation films on various polymers, which were ideally adapted for the angular compensation of STN computer monitors. All above-mentioned solutions are primarily intended for the angular compensation of the contrast in multi-plexially monitored LC monitors, in which the homeotropic orientation of the LC molecules in the selected pixel is not entirely feasible. For this reason, such solutions are neither technically nor economically appropriate for the above-mentioned technical problem, that is the angular compensation of LC optical light shutters, operating on the principle of electrically controlled birefringence, in a the state with highly homeotropically aligned LC molecules.

Interesting are also techniques for solving the above represented technical problem of angular compensation of LC optical light shutters, operating on the principle of electrically controlled birefringence, which are devised to utilize a plurality of liquid crystal cells (#5). Technical solutions based on the complementary orientation of two standard TN cells (Twist Nematic – the rotation of the LC structure being 90.degree.) adapted in such a manner, that their angular dependences compensate each other, are used in manufacture by the majority of manufacturers (Optrel, Xelux, Jackson,...) The technical solution of the ESAB company (Hornell, US 4,240,709) is important as well; it employs two TN cells, one of which is functioning in the passive mode (a substantially reduced angular dependence of the contrast), and the other in the active mode. In the »passive«TN cell there is used a twist angle of the LC cell of 60.degree.-90.degree. The Speedglass company claims in the patent (Hornel *et al.*, EP 706,674, WO 9,529,428, US 5,825,441) the use of two complementary TN cells, characterized by a rotation of the LC structures of less than 90.degree.; in patent applications (Hornel *et al.*, EP 805,661, WO 9,715,254) and (Hornel *et al.*, EP 858,305, WO 9,715,255) the same company amends its basic idea of exploiting two complementary TN cells, using a LC structure rotation of less than 90.degree., with the aid of the low-frequency control of LCD shutters, and an additional retardation layer. With the utilization of several LC cells the angular compensation problem is solved also in US 5,515,186 (Fergasson *et al.*). The compensation of the angular dependence in such a mode is, however, relatively expensive, as each additional LC cell substantially increases the manufacturing costs of the light shutters.

It has to be recognized as well, that the problem of the angular compensation of the layers of homeotropically oriented LC molecules is directly correlated with the problem of the angular dependence of the crossed polarizers *per se*, which are the subcomponent of each LC electro-optical shutter element, operating on the principle of electrically controlled optical birefrigence. In recent years, several authors have disclosed basic

principles for the solution of this problem. The suggested solutions are based on the utilization of at least two additional birefringent layers sandwiched between the LC cell, and the input and output polarizers. K. Ohmuro *et al.*, Fujitsu company, Japan, (SID'97, 1, p 845) show that the problem is quite successfully solvable by the utilization of three birefringent layers, two of which are negatively birefringent, and have a fast optical axis oriented perpendicularly to the liquid crystal layer plane (parallel to the homeotropically oriented LC molecules), and one of which is positively birefringent and has the optical axis oriented parallel to the liquid crystal layer plane (perpendicularly to the homeotropically oriented LC molecules!). The majority of other authors, such as H.Mori, P.Bos (IDRC'97, p M-88), J.Chen *et al.*, Samsung company, Korea (SID'98 Digest, p 315), devise their technical solutions on the utilization of effectively two additional negatively birefringent layers, one of which has the fast axis parallel to the polarization axis of the analyzer, and causes a relative phase delay between the ordinary and the extraordinary rays for 1/4 of the light wavelength, and is denominated $\lambda/4$ plate. The combination of such a $\lambda/4$ plate, oriented in the above manner, with a correspondingly thick additional birefringent plate exhibiting an optical birefringence with the same sign, and an optical axis oriented in perpendicular direction with respect to the liquid crystal layer, that is parallel to the homeotropically oriented LC molecules, significantly improves the angular dependence of the light attenuation in crossed polarizers.

Although there is a slight similarity with respect to the deformation of the otherwise isotropic polymeric molecules, the claimed technical solution differs significantly from the hitherto optimal state of the art solutions:

- Solution #1 Group: Uchida, Stanley,...
- Solution #2 Group: Harris and Cheng, Hughes,...
- Solution #3 Group: NITO Denko, Sumitomo Chemicals...

in the procedure applied to achieve the corresponding deformation of the polymer molecules.

Uchida, Stanley (#1) and Nito as well as Sumitomo Chemicals (#3) employ the principle of two- or one-dimensional stretching of a preformed, that is a polymerized thermoplastic polymeric sheet. On the other hand, Harris and Cheng and Hughes (#2) utilize the method of alignment of long molecular segments by means of a specific method of deposition of a prepolymerized polymer solution, such as the deposition of a preimidized polyimide on a rotating plate.

The present invention is based on the utilization of the volume contraction of the polymer during the very polymerization process, so that the monomer layer is during the polymerization in contact with the surface of at least one rigid flat plate, or is preferably sandwiched between two layers of thermally and mechanically stable, rigid materials, for example glass. In such a manner, strains are generated in the material in the plane, determined by the rigid boundary surfaces, and causing the corresponding deformation of otherwise isotropic macromolecules. Since this deformation of the macromolecules is effected during the polymerization process, the cross-polymerization permanently freezes the molecules in their deformed state, which is of the utmost importance for the long-term and thermal stability of the birefringent films, manufactured in such a manner. The term »freezes« should be interpreted in the sense of »hardens« or »becomes rigid« respectively. The very deformation of the macromolecules effected with cross-polymerization, endows the present invention with substantional advantages in comparison with hitherto known methods of stretching preformed that is polymerized polymeric sheets. The latter has been achieved by hitherto known processes either by means of a direct, more or less one-dimensional mechanical stretching, of the type utilized in the above mentioned technical solution #3 Group (Nitto, Sumitomo,...), or by means of a homogeneous, two-dimensional stretching of the thermoplastic polymeric sheet in the vicinity of the glass phase transition of the employed polymer, which is characteristic for the #1 Group of the above itemized known technical solutions – Uchida, Stanley,.... The claimed process does not

require technically sophisticated equipment for the controlled mechanical stretching. It enables mass production, and furthermore, may be adapted in such a manner, that the obtained negatively birefringent polymer layer exerts simultaneously a bonding action, that is the adhesion and the optical contact between the LCD cell, and the polarizing filter.

The present invention enables, in comparison with the technical solutions #2 a substantially reduced deformation of the molecules, thus requiring thicker layers. The manufacturing process is, however, less expensive, more flexible and enables a significantly broader choice of the materials, as well as an improved precision and reproducibility. An important advantage is also the possible adaptation of the manufacturing process, enabling the simultaneous adjustment of the thickness of the compensating polymeric layer to the individual LCD optical shutters, that is the adjustment as to the thickness and birefringence of the liquid crystal layer, the chosen polarizer, etc. This is not feasible in any of the three prior art processes, which require either an extraordinary exacting one- or multi-dimensional stretching (technical solutions #1 and #3), or an extraordinary sophisticated method for the deposition of the compensating layer (technical solutions #2). Feasible is only the mass production of the compensation sheet exhibiting a determined selected retardation value, which is, however, not necessarily optimal for the selected configuration of the LCD optical shutter. The characteristics of the selected configuration are influenced primarily by the thickness and the refractive index of the liquid crystal layer, the selected polarizers, etc.

The present solution is completely different from the technical solutions #4 Group (Fuji, Akzo-Nobel,...). The latter are indeed of high technical quality, the methods are, however, highly sophisticated and expensive. A mass production of a compensation layer with exactly defined characteristics is involved, which in principle impedes the adjustment to the specific characteristics of the individual LCD shutters. At the same time it has to be emphasised that such materials cannot be simultaneously utilized for the

bonding of the individual subcomponents of the LCD shutter into a functional unity.

In comparison with hitherto known technical solutions, based on the utilization of several LC cells (#5), the claimed invention enables a significantly less expensive and simpler application of the present process. The employment of each supplementary LC cell renders in fact the product significantly more expensive; furthermore, other important optical characteristics, such as light scattering, are deteriorated.

The object of this invention is a process for manufacturing a polymeric optical compensation layer for LCD optical shutters, and the corresponding construction of such a shutter. The process ought to enable the manufacture of an optically negatively birefringent compensation layer, based on the controlled, spontaneous deformation of the polymeric macromolecules during the formation of the polymeric layer. The deformation of the polymeric macromolecules should result from the volume shrinkage of the polymer volume during the polymerization process, if the polymer layer is during the polymerization continually in contact with at least one rigid plate surface. Preferably, however, it is sandwiched between two rigid surfaces, under the provision, that the shrinkage of the polymer is unrestrained in the direction perpendicular to the surface plane. The expression "unrestrained" means, that it is in fact unrestrained, or that the mechanical strains in the direction perpendicular to the surface plane, are significantly reduced in comparison with the strains in the layer plane. The optically birefringent polymer compensation layer, manufactured in accordance with the present invention, ought to enable an easy adjustment to the specific characteristics of the individual LCD optical shutters, by means of adjusting the thickness of the layer *per se*, and the polymerization conditions.

In addition to the compensation of the angular dependence of the optical characteristics (light attenuation, ...) of the LCD optical shutter, the

obtained optically negatively birefringent layer can also act simultaneously as an optical contact adhesive, combining the individual subcomponents of the LCD optical shutter into a functional unity.

According to this invention, the object is achieved in conformance with the appended claims.

In the text bellow, the invention is exemplified and illustrated with the aid of drawings, representing:

FIG. 1: a schematic depiction of a polymer macromolecule that is not deformed, and a macromolecule deformed according to the claimed process;

FIG. 2: a schematic illustration of the process for manufacturing an optically negatively birefringent polymer layer by the employment of soft spacers,

FIG. 3: a schematic illustration of the process for manufacturing an optically negatively birefringent polymer layer by employing a two-stage polymerization of the polymeric compensation layer, and hard spacers, which are removed prior to the second polymerization stage;

FIG. 4: a schematic representation of the construction of an angularly compensated LC optical shutter, enabling the angular compensation of the birefringence of the LC layer:

- a- exemplifying mechanically stable polarizers;
- b- exemplifying an additional glass plate, protecting the mechanically sensitive polarizers,

FIG. 5: a schematic representation of the construction of an angularly compensated LC optical shutter, enabling the angular compensation of the birefringence of the LC layer, and the crossed polarizers.

The solution suggested by this invention resides in the spontaneous deformation of the molecules of certain polymeric materials, such as polyurethanes, polycarbonates, various polymeric materials for plastic lenses, such as allyl-diglycol-carbonate (ADC), laminating materials for

polarization films, such as cellulose-aceto-butyrate (CAB), and cellulose-triacetate (TAC) etc., materials respectively. The deformation is caused by the volume shrinkage of the material during the thermally and UV triggered polymerization, under the provision, that during the polymerization the monomer layer is in direct contact with at least one rigid plate surface, or is sandwiched between two layers of rigid, thermally and mechanically stable materials, such as glass.

Monomeric and prepolymeric materials, appropriate for this technical solution, are especially those that by virtue of their chemical structure, being already polymerized, during the linear stretching tend to become optically positively birefringent, having the main axis of the refractive index tensor, that is the optical axis, oriented in the direction of the mechanical deformation, that is the stretching.

During polymerization the polymeric mass adheres to the boundary surface of the rigid plate. The spontaneous volume shrinkage of the polymer during the polymerization results in the generation of mechanical strains in the material. This enables the free shrinkage of the material in the direction perpendicular to the polymeric layer plane (in the thickness direction), that is the axis z, leaving only the strains on the polymer layer plane, which are the axes x, y; in the direction of the axis z, however, the mechanical strains are substantially diminished. These strains cause a deformation of the otherwise isotropic molecules of the polymer, to become flattened in the z axis direction, and they become uniformly stretched in all directions in the x, y plane of the polymeric layer, as represented in FIG. 1. The employment of materials exhibiting the above-mentioned positive stretching characteristics yields an optically negatively birefringent layer.

Triggering the polymerization at elevated temperatures can enhance the deformation of the macromolecules during the polymerization process. Thus

the differences between the thermal stretching of the polymer and the rigid boundary surfaces increase the deformation of the macromolecules.

The selection of appropriate conditions for the technical procedure, especially the thickness of the layer, the chemical composition of the boundary plate surfaces, the polymerization time-velocity profile, etc., endows the obtained polymeric layer with desired optically negatively birefringent characteristics. These optical characteristics make possible the angular compensation of the intensity of the transmitted light for the homeotropically aligned LC molecular layer in the LC optical shutter, which generally shows an optically positive birefringence. The appropriate selection of the thickness of the compensation polymeric layer enables the compensation of the angular dependence of the contrast/attenuation of the LC shutter. Thus, the optical thickness of the compensation layer, which is the product of the birefringence (Δn) and the thickness of the layer (d) → ($\Delta n_{polymer} \times d_{polymer}$), is equal to the optical thickness of the liquid crystal layer, that is the product of the birefringence and the thickness of the layer ($\Delta n_{LC} \times d_{LC}$).

Owing to the three-dimensional shrinkage during the polymerization, the complete process has to be performed in such a manner, that the strains are generated only in the x, y plane of the polymer compensation layer, while the strains in the z direction (in the thickness direction), perpendicular to the surface, have to be minimal. The strains in the direction of the z axis can be avoided by allowing the free variation of the thickness of the compensation layer, thus displacing at least one boundary layer in the direction of the z axis during the polymerization process.

This can be achieved in several ways, in conformance with three basic ideas:

- With the utilization of soft spacers, easily deformable under pressure, between the boundary surfaces of the polymeric compensation layer,

by means of which the thickness of the prepolymer layer is adjusted prior to the polymerization, and simultaneously easily deformed by the action of forces generated by the shrinkage of the material during the polymerization, thus enabling a free shrinkage in the direction of the z axis.

- By means of a gradual or multi-stage, preferably two-stage polymerization, wherein the thickness of the layer between two rigid boundary surfaces of the polymer mass (monomer and prepolymer respectively), is at the beginning adjusted by hard spacers, and the polymerization proceeds to the point only, at which due to the viscosity and the surface activity the leakage of the polymer mass is no longer possible. Then the rigid spacers ensuring the corresponding thickness of the polymer layer are removed, and the polymerization process is completed in such a manner, that it enables the unrestrained shrinkage of the polymer in the z direction perpendicular to the layer plane.
- By pouring an appropriate prepolymer layer of controlled thickness on a rigid support thus enabling the unrestrained shrinkage of the thickness of the polymer layer in the z axis direction. The process for the polymerization of the prepolymer mass proceeds in contact with at least one boundary surface.

The following Examples are working embodiments, describing the process for manufacturing a polymer layer exhibiting an optically negative birefringence, as well as the construction of the LC optical shutter *per se*, with the utilization of such a polymer layer for the compensation of the angular dependence of the light attenuation.

<u>Example 1</u>

A. Process for the manufacture of an optically negatively birefringent polymer layer

a) Single-stage polymerization - soft spacers

A polymeric, negatively birefringent compensation layer is formed between two rigid boundary surfaces as represented in FIG. 2. The spacing between the boundary surfaces 1,2, preferably glass plates having a mutual distance equal to the thickness d, is filled up with the monomer or prepolymer mass 3 respectively. Appropriate are monomeric or prepolymeric materials, which by virtue of their chemical structure, already in their polymerized form tend to become optically positively birefringent during linear stretching, having the main axis of the refractive index tensor, that is the optical axis, oriented in the direction of the mechanical stretching, for example a polyurethane-epoxy copolymer with a UV light activator. The spacing between the surfaces or the prepolymer layer thickness respectively, is determined by means of the spacers 4, the so-called soft spacers, manufactured in a separate process from an appropriate material, for example a silicone gel having appropriate dimensions and such a hardness as to remain undeformed at pressures resulting from the weight of the boundary plate having the surface 1, as well as the surface tension in the non-polymerized material layer.

The layer is heated to an elevated temperature, for example 60°C to 80°C, and the resulting thermal expansion causes an additional increase of the strains, which are responsible for the deformation of the polymer macromolecules. An intensive, highly homogeneous UV light emitted preferably by a 300 – 1000 W light source, predominantly in the UV spectral domain, is employed to trigger the polymerization of the prepolymer mass layer 3 in FIG. 2, which is terminated in an appropriate period of time. During the very polymerization procedure the temperature of the polymeric layer may begin to decrease, so that the final cross-linking, that is the cross-polymerization, can take place in a more or less cool material. In the course of the polymerization, the volume shrinkage of the polymeric layer results in the generation of strains within the layer. The exertion of these forces causes the deformation of the soft spacers 4, and enables the unrestricted shrinkage of the polymer layer 3 in the direction perpendicular to the layer plane or in the direction of the z axis respectively, while the strains in the plane of the x,y

axes remain, owing to the adhesion on the surfaces of the rigid boundary plates 1,2. The polymer macromolecules thus acquire the typical deformation, as depicted in FIG.1. The cross-polymerization permanently »freezes« the molecules in their deformed state; this is of the utmost importance for a long-term and thermal stability of the birefringent polymeric films obtained in such a manner.

The expression »freezes« is employed in the meaning of »hardens« or »becomes rigid« respectively. After the polymerization the rigid boundary plates are optionally removed. The obtained optically negatively birefringent polymer layer may be utilized as an autonomous optically negatively birefringent element in various applications. In superior articles, for example in protecting welding filters, which are predominantly multi-layer laminates made of different layers, such as infrared light reflectors, polarization filters, and the like, the boundary layers may be provided by the individual elements of such optical asssembly, and the above-described polymeric layer acts supplementary to the optical angular compensation of the homeotropically oriented LC molecules simultaneously as a bonding layer and as an opical contact.

b) Two-stage polymerization - hard spacers

The process is initiated as in Example a), except that the spacing between the plates having the surfaces 1,2, is determined by the hard spacers 5 in FIG: 3; in conjunction with the aperture 9 in the upper support 8 it enables the illumination of the prepolymer layer 3 with UV light. The polymerization is operated in two stages. The first polymerization stage is preferably activated at room temperature by means of a relatively weak UV light, advantageously provided by a 150 W light source 6 in the UV A spectral domain. The total visible area of the prepolymer mass layer 3 is illuminated as homogeneously as possible, and the illumination is interrupted immediately or within a few seconds after the viscosity reaches the level, at which it impedes in

conjunction with the surface tension the leakage of the partially polymerized mass.

The termination of the first stage of the partial polymerization is followed by the removal of the hard spacers 5 ensuring the proper thickness of the polymer layer. Identically as in Example a), the layer is subsequently in the second stage, optionally thermally or by UV activation, heated to an elevated temperature, preferably 60°C to 80°C to enhance additionally by thermal stretching the strains responsible for the deformation of the polymer macromolecules. The intense, highly homogeneous UV light, which is preferably provided by a 300-1000 W light source predominantly in the UV A spectral domain, triggers the process of the final polymerization of the prepolymer mass that is accomplished in some ten seconds. During the very polymerization process the temperature of the polymer layer may begin to decrease, so that the final cross-linking occurs in the more or less cool material. The cross-polymerization permanently freezes the molecules in the deformed state, which is of the utmost importance for a long-term and thermal stability of the birefringent polymer films manufactured in such a manner. Identically as in Example a), the rigid boundary plates are optionally removed, and the obtained optically negatively birefringent polymer layer may be utilized as an autonomous, optically negatively birefringent element in various applications. In superior articles, for example in protective welding filters, which are predominantly multi-layer laminates made of different layers, such as infrared light reflectors, polarization films and the like, the boundary layers may be provided by the individual elements of such an optical assembly. The above-described polymer layer functions as an optical angular compensation layer for the homeotropically oriented LC molecules, as well as simultaneously as a bonding layer and an optical contact.

Optionally the polymer mass is in the first stage illuminated at the margins only of the polymer layers, outside the usable, namely is the viewing area of the later optically negatively birefringent compensation layer. The polymerization or the illumination with UV light respectively, is interrupted as soon as the hardness of the material in the illuminated region increases to the point, at which the polymerized areas function as soft spacers.

The processes for the manufacture of the polymer compensation layer for LC optical shutters having the optical axis perpendicular to its surface plane, are characterized in:

- that the monomer or prepolymer mass is poured on a rigid boundary surface, and the polymerization of the prepolymer mass proceeds in contact with at least one rigid boundary surface;
- that the monomer or prepolymer mass is poured between two rigid boundary surfaces separated by soft spacers, which are deformed under pressure, in such a way that the polymerization of the prepolymer proceeds in contact with the two rigid boundary surfaces;
- that the monomer or prepolymer mass is poured between the two rigid surfaces divided by hard spacers, and the polymerization of the prepolymer mass in contact with the two rigid boundary surfaces proceeds at first only to the level, at which the viscosity of the mass is increased to the point at which it does not leak out, whereupon the hard spacers are removed and the polymerization process proceeds to the end.

The expression "poured" is to be understood in the broadest interpretation, which means that there may in fact be poured on a rigid boundary surface, or sandwiched, with the aid of the surface tension effect, between two rigid boundary surfaces, or poured on one rigid boundary surface, and the other rigid boundary surface is applied to the layer after the pouring.

The polymerization process is either thermally or UV activated, and is operated at elevated temperature, which is at least somewhat lower than the

glass phase transition of the polymer. In most cases the attained optical birefringence of the polymer layer may be optionally decreased in a suitable, controlled way, by means of reheating the polymer layer in the vicinity of the glass phase transition of the polymer. The polymerization is at least at the beginning activated by means of UV light. The activation with the UV light 6 proceeds optionally in two stages, so that in the first stage, when the thickness of the layer is determined by the hard spacers 5, it proceeds to the level only, at which the increased viscosity stabilizes the thickness of the layer 3 to the point at which the hard spacers are removable, and so the next phase of the UV-activation enables the operation of the polymerization without the generation of strains in the direction perpendicular to the compensation layer 3.

B. The construction of an angularly compensated LCD optical shutter

The process for manufacturing an optically negatively birefringent layer according to this invention enables an entirely novel constructional solution of manufacturing angularly compensated optical LC light shutters. Such a layer performs the basic function of compensating for the angular dependence of the optically positive birefringence of the homeotropically oriented layer of the liquid crystal, as well as the bonding of the subcomponents into a mechanically and optically uniform assembly, and further ensures the optical contact, which is not feasible by any of the prior art technical solutions.

The construction according to this invention is performed in such a manner, that one or both polarizers, which in conjunction with the LC cell form the optical shutter, are not directly laminated to the LC cell, but to one of the outer protecting layers, for example to a glass or IR/UV filter, and subsequently, by means of the optically negatively birefringent polymer layer combined according to the invention with the LC cell into a mechanically and optically uniform assembly.

In general, two concepts for the optical compensation of the LC light shutters are involved.

a. The compensation of the angular dependence of the optically positive birefringence in a homeotropically oriented LC layer in a LC cell.

b. The compensation of the angular dependence of the optionally positive birefringence in a homeotropically oriented LC layer in a LC cell, as well as the angular dependence of polarizers crossed perpendicularly to each other and forming in conjunction with the LC cell an LC optical shutter.

Ad a. In most cases, the compensating for the angular dependence of the optically positively birefringence of the homeotropically oriented liquid crystal layer in the LC cell 13, fulfils the technical requirements in a completely sufficient manner, and thus the construction of such a LC optical shutter represented in FIG. 4, is simplified. Inasmuch as the outer layers of the polarization film may withstand the mechanical pressure in the x,y plane of the polarization filter, generated during the above-described polymerization process (according to the working Examples Aa and Ab) of the optically negatively birefringent layer 3, the preferred and most appropriate construction is at first the bonding, by means of a standard isotropic adhesive 17, of the polarizer 15 with one of the outer protective layers corresponding to the boundary surfaces 2, such as glass, and a LC cell 13, the polarizer/analyzer 12 and the IR/UV reflector 11, to yield two autonomous assemblies. The obtained components of the LC shutter are combined in accordance with the above-described process into a unity by means of bonding with an appropriate polymer layer 3, such as a polyurethane-epoxy copolymer with an UV light activator. Such a construction of the optical shutter is represented in FIG. 4a.

The conditions in the manufacture of the shutter should be strictly controlled, in conformance with the described process of manufacturing the optically negatively birefringent polymer layer, in respect of the working Examples Aa and Ab, as well as in respect of the mechanical construction, which has to

secure a strictly defined and controlled thickness of the layer, for example 300 μm, as well as the polymerization conditions: temperature profile, UV light illumination procedure, so that the optically negative birefringence is induced in the polymer layer 3 during the polymerization. The appropriate performance of the whole process, that is with soft spacers or the multi-stage polymerization enables the perpendicular orientation of the principal axis of the refractive index tensor with respect to the layer. If simultaneously its optical thickness is such, that the integral optical thickness, that is the multiplication product of the birefringence and the thickness of the layer ($\Delta n_{polymer} \times d_{polymer}$), of this layer and the optical thickness of the two polarization filters, which themselves exhibit slightly optically negatively birefringent characteristics, is equal to the optical thickness of the homeotropically oriented liquid crystal layer, that is the multiplication product of the birefringence and the thickness of the layer ($\Delta n_{LC} \times d_{LC}$), the requirement for the compensation of the angular dependence of the contrast/attenuation of the LC shutter is fulfilled. In addition to this basic function the said layer also combines the two subcomponents into a mechanically and optically uniform assembly, and ensures the optical contact.

If the outer layers of the polarization filters do not withstand the mechanical pressure in the x-y plane of the polarization filter, generated during the above-described polymerization of the optically negatively birefringent layer, the preferred and most suitable construction is represented in FIG. 4b. In this case the optically negatively birefringent compensation polymer layer 3 is formed between one of the surfaces of the LC cell 13, and an additional, preferably glass plate 18, which is an effective protection for the polarizer/analyzer 15. This manufactured assembly consisting of the LC cell 13 and the optically negatively birefringent polymer layer 3, sandwiched between one of the outer glasses of the LC cell 13 and the additional, preferably glass plate 18, is laminated on both outer surfaces with the crossed polarizers 12 and 15 by means of a standard isotropic adhesive 17,

such as a silicone gel and the like. This optical shutter exhibits significantly improved characteristics in comparison with a standard LC optical shutter.

It is understood, that it is optionally possible to combine the two polarizers with the LC cell by means of the optically negatively birefringent polymer compensation layer in conformance with the invention, instead of the standard optically isotropic adhesive. In this case, however, the sum of the optical thicknesses of the two polymer layers and the optical thickness of the two polarization filters, which themselves exhibit slightly optically negatively birefringent characteristics, has to be equal to the optical thickness of the homeotropically oriented liquid crystal layer, that is the multiplication product of the birefringence and the thickness of the layer ($\Delta n_{LC} \times d_{LC}$); the requirement for the compensation of the angular dependence of the contrast/attenuation of the LC shutter is thus fulfilled.

Ad b. The constructions of the angularly compensated LC optical shutter, described in the working Example a), solve exclusively the problem of the angle-dependent birefringence of the layers of homeotropically oriented LC molecules. They do not, however, solve the problem of the angular dependence of the crossed polarizers themselves, which are the components of any LC electro-optical shutter element operating on the principle of electrically controlled optical birefringence. The utilization of an optically negatively birefringent layer, that is the object of the claimed invention, enables the optimal constructional embodiment, and at the same time ensures the angular compensation of the birefringence of the homeotropically oriented LC molecules, as well as the compensation of the angular compensation of the crossed polarizers with the use of an additional $\lambda/4$ plate. Since the optical retardation layers are significantly dependent on the wavelenght of the light, is an ideal example for the utilization of the above-mentioned angular compensation principle the protective welding filter requiring for the supplementary eye protection from UV and IR light, an additional filter for the yellow-green light of the wavelenght approximately

550 nm. FIG. 5 depicts the construction of such a shutter, which is a multi-layer laminate. It is composed of: a thin-layer IR/UV filter 11 that at the same time ensures the protection from the harming IR and UV light, as well as the selective transmittance of the light having a wavelenght of 550 nm, corresponding to the $\lambda/4$ plate, of two crossed polarizers 12, 15, and a LC cell 13 in the closed state with homeotropically oriented molecules, exhibiting an optical birefringence Δn_{LC} and having a thickness d_{LC}, a polymer layer 3 of a thickness (L) exhibiting an optically negative birefringence Δn_L and having an optical axis directed perpendicularly to the layer itself, a $\lambda/4$ plate 19 for the light of a wavelenght of 550 nm, exhibiting an optically positive optical birefringence, the slow axis of which is parallel to the polarization transmission axis of the polarizer/analyzer 15 and the protective glass surface 2. The basic idea is, that the optical thickness (Δn_1 x l) of the optically negatively birefringent polymer layer 3 in this case does not adapt directly to the optical thickness of the liquid crystal layer, as in the working Example Ba. In this case it has to be secured, that the thickness (L) of the optically negatively birefringent layer 3 of the optical adhesive layer in conjunction with the negative birefringence of the two polarizers is such, that the difference of the refractive indices for the ordinary and the extraordinary rays (Δn_L) is such, that the difference of the optical paths for the ordinary and the extraordinary rays (Δn_L x L) is smaller than the difference of the optical paths for the ordinary and the extraordinary rays in the LC cell 13 with homeotropically oriented molecules (Δn_{LC} x d_{LC}). In such a way the optically uncompensated part of the LC layer 13 operates as an optically positively birefringent plate, the optical axis of which is perpendicular to the axis of the $\lambda/4$ plate 19, while the difference of the optical paths in this part of the layer is such that together with the $\lambda/4$ plate 19 it ensures the angular compensation of the two polarizers 12,15 of the LC light shutter.

The preferred constructions are as follows:

- At least one of the polarizers 12,15 is laminated with an isotropic contact adhesive to the outside protective plate 2 of the light shutter instead of directly to the LC cell, so that there is a polymer layer 3 between at least

one of the polarizers 12,15, and between at least one of the boundary surfaces of the LC shutter. According to this invention, the polymerization is performed in such a manner that the polymer performs the function of combining the subcomponents of the LC shutter into a functional unity, while at the same time ensuring the angular compensation of the LC shutter in the state, in which the molecules are homeotropically oriented with respect to the boundary surfaces of the LC shutter.

- The optically negatively birefringent polymer layer 3 is deposited on one of the boundary surfaces of the LC cell 3, so that said polymer layer is sandwiched between the surface of the LC cell 13 and the rigid transparent, preferably glass plate 18. Two crossed polarizers 12, 15 are laminated with an isotropic optical adhesive 17 on each of the boundary surfaces of such assembly, and the protective outer glass plate 2 and an IR/UV filter 11 are laminated to these polarizers by means of an isotropic optical adhesive 17 as well.

- The construction of a LC light shutter with the use of an optically negatively birefringent polymer adhesive layer 3, optionally comprising an additional optically negatively birefringent layer between the polarizer and the LC cell. The thickness of the layer 3 corresponds to the requirement for the $\lambda/4$ plate 19, the slow axis of which is parallel to the polarization (transmittance) axis of the polarizer/analyzer 15, wherein the thickness (L) of the optically negatively birefringent polymer adhesive layer 3 is such, that the difference between the refractive indices for the ordinary and the extraordinary rays (Δn) is such, that the difference of the optical paths for the ordinary and the extraordinary rays ($\Delta n_L \times L$) is smaller than the difference of the optical paths for the ordinary and the extraordinary rays in the LC cell with homeotropically oriented molecules ($\Delta n_{LC} \times d_{LC}$). Thus the optically negatively birefringent polymer adhesive layer 3, the optically negative birefringence of the polarizer 12, and the optically uncompensated part of the LC layer in the LC cell 13 operate as a optically positively birefringent plate, the optical axis of which is perpendicular to the axis of the $\lambda/4$ plate 19, while the difference of the optical paths in this part of the layer is such that in

conjunction with the $\lambda/4$ plate 19 it ensures the angular compensation of the two crossed polarizers in the LC light shutter.

- The construction of a LC light shutter with the use of an optically negatively birefringent polymer adhesive layer 3, and as alternative optionally an additional optically negatively birefringent layer sandwiched between the polarizer and the LC cell, the thickness of which corresponds to the requirement for the $\lambda/4$ plate 19, the fast axis of which is parallel to the polarization axis of the polarizer/analyzer 15. The thickness (L) of the optically negatively birefringent polymer adhesive layer 3 is such, that the difference of the optical paths for the ordinary and the extraordinary rays ($\Delta n_L \times L$) is greater than the difference of the optical paths for the ordinary and the extraordinary rays in the LC cell 13 with homeotropically oriented molecules ($\Delta n_{LC} \times d_{LC}$), in such a manner that with the LC layer and the optically negative birefringence of the polarizer 12, the optically uncompensated part of the optically negatively birefringent polymer adhesive layer 3 operates as an optically negatively birefringent plate, the optical axis of which is perpendicular to the axis of the $\lambda/4$ plate 19, while the difference of the optical paths in this part of the layer is such that in conjunction with the $\lambda/4$ plate 19 it ensures the angular compensation of the crossed polarizers 12,15 in the LC light shutter.

It should be emphasized, that the described Examples represent only a few feasible working embodiments of the claimed invention. Various modifications and variations can be made within the scope of this invention, such as the utilization of a $\lambda/4$ plate exhibiting an optically negative birefringence, the employment of an additional glass plate, which mechanically separates/protects the polarizer and the $\lambda/4$ plate respectively, from the optically negatively birefringent polymer compensation layer, and the like.

PATENT CLAIMS

1. A process for the manufacture of the optical compensation polymer layer for the LC optical light shutter, which has the optical axis perpendicular to its surface, characterized in that it utilizes the mechanical strains resulting from the shrinking of the polymer during the polymerization process, while in contact with at least one rigid boundary surface, but preferably between two rigid boundary surfaces in such a way,

- that the monomer or prepolymer mass is poured as a layer between the two rigid surfaces separated by soft spacers, which are deformed under pressure generated in the layer as a result of the shrinkage during the polymerization, in such a way, that the mechanical strains in the direction perpendicular to the surface are significantly smaller than within the plane of the polymer layer, or
- that the monomer or prepolymer mass is poured between the two rigid surfaces divided by the hard spacers, and the polymerization process of the prepolymer mass in contact with the two rigid boundary surfaces proceeds to the level only, at which the viscosity of the mass is increased to the point, where it does not leak out, followed by the removal of the hard spacers, and the polymerization process proceeds to the end in such a way, that the polymer layer is capable of unrestrained shrinking in the direction perpendicular to the layer during further polymerization.

2. A process for the manufacture of the optical compensation polymer layer for the LC optical light shutter according to claim 1, characterized in that the polymerization is thermally activated at a temperature which is somewhat lower than the glass phase transition of the polymer, and that the achieved optical birefringence can be optically adequately reduced by reheating the polymer layer close to the temperature of the glass phase transition of the polymer.

3. A process for the manufacture of the optical compensation polymer layer for the LC optical light shutter according to claim 1, characterized in that the polymerization is activated at least at the beginning by means of UV light.

4. A process for the manufacture of the optical compensation polymer layer for the LC optical light shutter according to claims 1 and 3, characterized in that the polymerization takes place at an elevated temperature, which is lower than the temperature of the glass phase transition of the polymer used.

5. A process for the manufacture of the optical compensation polymer layer for the LCD optical light shutter according to claims 1, 3 and 4, characterized in that the activation of the polymerization by means of UV light (6) takes place in two stages, so that in the first stage - when the thickness of the layer is determined by the hard spacers (5) - it proceeds only to the level at which the increased viscosity stabilizes the thickness of the layer (3), to the point at which the hard spacers can be removed, and so the next phase of the UV activated polymerization enables the polymerization to proceed to the end almost without mechanical strains in the direction perpendicular to the compensation polymer layer (3).

6. The construction of a LC optical light shutter, characterized in that at least one of the polarizers (12, 15) is directly laminated by means of the isotropic contact adhesive to the outside protective surface (2) of the light shutter instead of directly to the LC cell (13), so that there is a polymer layer (3) between at least one of the polarizers (12,15) and between one of the boundary surfaces of the LC shutter, polymerized in such a manner that it simultaneously performs the function of combining the subcomponents of the LC shutter into a functional unity, while at the same time ensuring the angular compensation of the LC shutter in the state in which the molecules are homeotropically oriented with respect to the boundary surfaces of the LC cells (13).

7. The construction of a LC optical light shutter, characterized in that the negatively birefringent polymer layer (3) is deposited on one of the boundary surfaces of the LC cell (13), so that said polymer layer (3) is sandwiched between the surface of the LC cell (13) and the rigid transparent, preferably glass plate (18), and that there are two crossed polarizers (12,15) laminated by means of an isotropic optical adhesive (17) on each of the boundary surfaces of such assembly, and the protective outer glass (2) and IR/UV filter (11) can be optionally laminated to the outer surfaces of said crossed polarizers by means of an isotropic optical adhesive.

8. The construction of a LC optical light shutter with the use of an optically negatively birefringent polymer adhesive layer (3), and an additional optically birefringent layer between one of the polarizers and the LC cell, the thickness of said polymer corresponding to the requirement for the $\lambda/4$ plate (19) for the specified spectral domain of the employed LC optical light shutter, and the slow axis of which is parallel to the polarization (transmission) axis of the polarizer/analyzer (15), characterized in that it uses an additional color light filter (11), which preferably selectively reflects/absorbs IR/UV light, and at the same time additionally limits the amplitude of the transmitted visible light to the spectral domain of the highest sensitivity of the human eye, and the thickness (L) of the negatively birefringent layer of the optical polymer adhesive layer (3) is such that the difference between the refractive indices for the ordinary and the extraordinary rays (Δn) is such that the difference of the optical path for the ordinary and the extraordinary rays ($\Delta n_L \times L$) is smaller than the difference of the optical paths for the ordinary and the extraordinary rays in the LC cell with homeotropically oriented molecules ($\Delta n_{LC} \times d_{LC}$), in such a way, that with the negatively birefringent layer of the optical polymer adhesive layer (3), and optically negative birefringence of the polarizer (12), the optically uncompensated part of the LC layer in the LC cell (13) operates as an optically positively birefringent plate, the optical axis of which is perpendicular to the axis of the $\lambda/4$ plate (19), while the difference of the

optical paths in this part of the layer is such that together with the $\lambda/4$ plate (19) it ensures the angular compensation of the crossed polarizers of the LC light shutter.

9. The construction of a LC optical light shutter with the use of an optically negatively birefringent polymer adhesive layer (3), and an additional optically birefringent layer between the polarizers and the LC cell, the thickness of said layer corresponding to the requirement for the $\lambda/4$ plate (19) for the specified spectral domain of the utilization of the LC optical light shutter, the slow axis of which is parallel to the polarization (transmission) axis of the polarizer/analyzer (15), characterized in that it employs an additional color light filter (11), which preferably selectively reflects/absorbs IR/UV light, and at the same time additionally limits the amplitude of the transmitted visible light to the spectral domain of the highest sensitivity of the human eye, and the thickness (L) of the optically negatively birefringent layer of the optical polymer adhesive layer (3) is such that the difference of the optical paths for the ordinary and the extraordinary rays ($\Delta n_L \times L$) is greater than the difference of the optical paths for the ordinary and the extraordinary rays in the LC cell (13) with homeotropically oriented molecules ($\Delta n_{LC} \times d_{LC}$) in such a way, that with the LC layer and optically negative birefringence of the polarizer (12), the optically uncompensated part of the negatively birefringent layer of the optical adhesive layer (3) works as a negatively birefringent plate, the optical axis of which is perpendicular to the axis of the $\lambda/4$ plate (19), while the difference of the optical paths in this part of the layer is such that together with the $\lambda/4$ plate (19) it ensures the angular compensation of the light extinction in the crossed polarizers (12,15) of the LC light shutter.

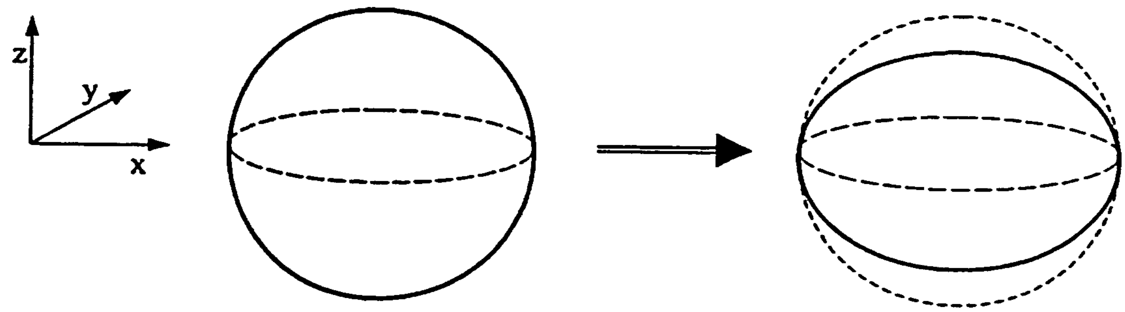

FIG. 1

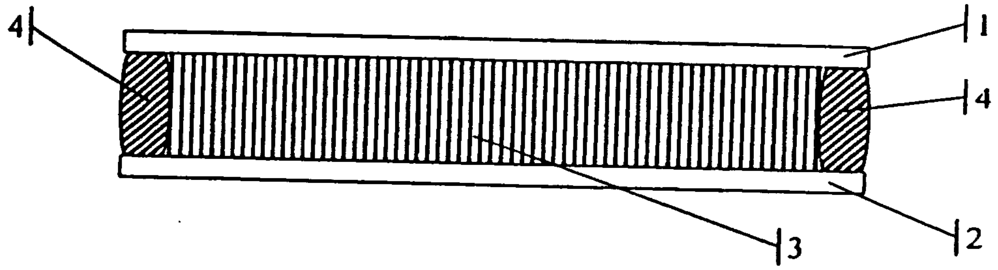

FIG. 2

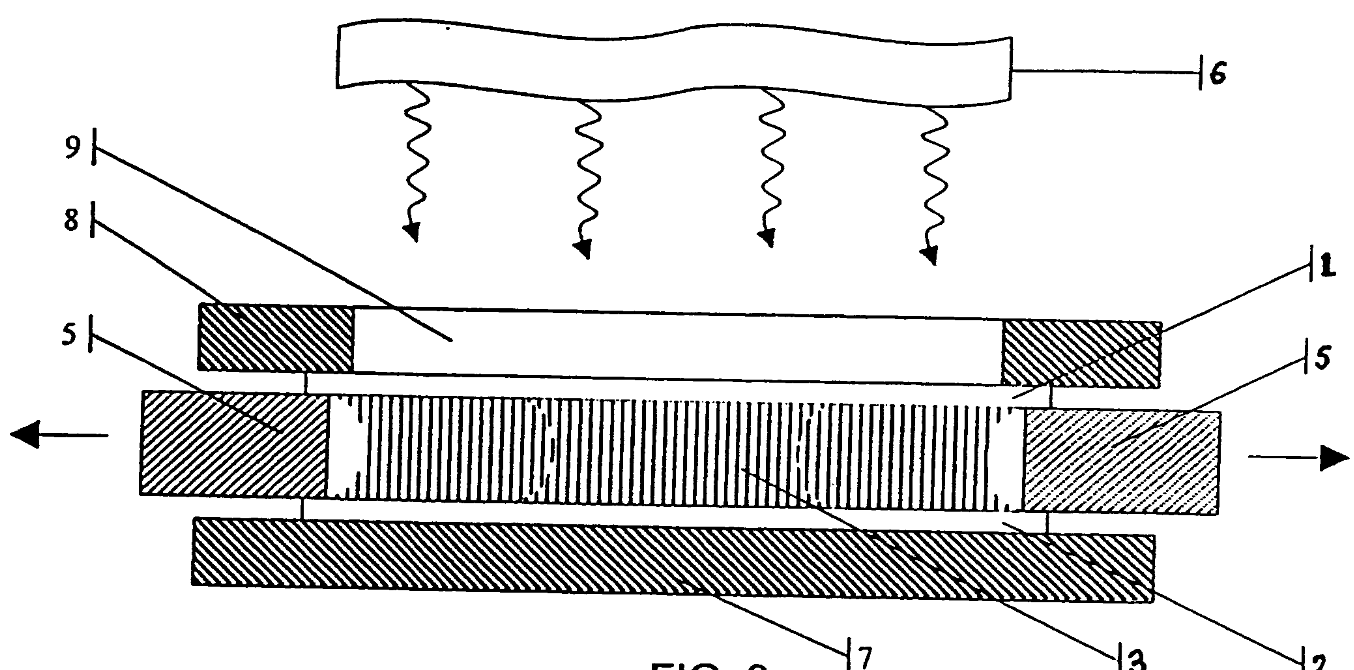

FIG. 3

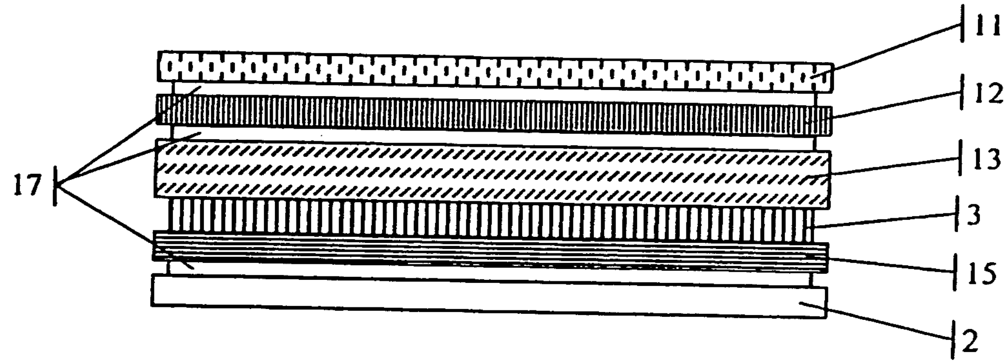

FIG. 4a

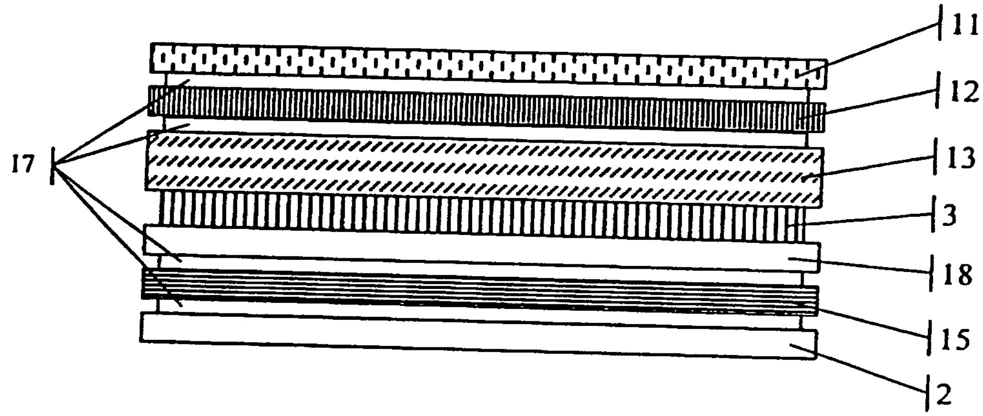

FIG. 4b

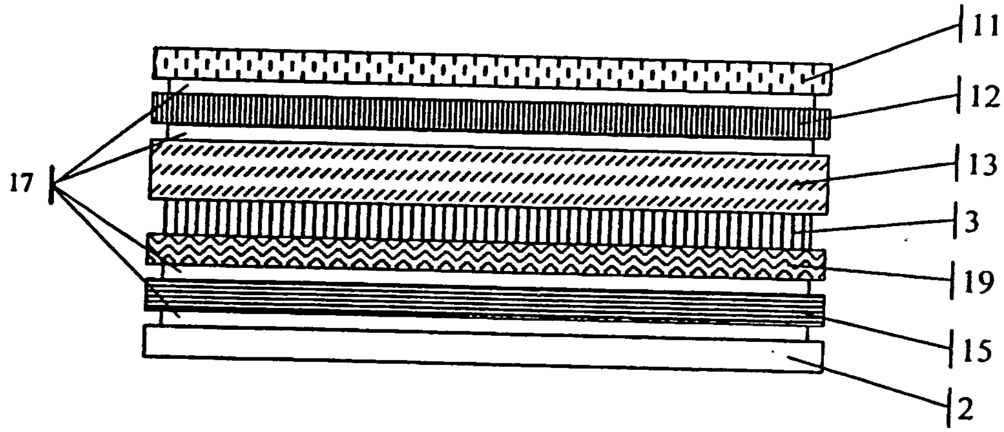

FIG. 5

PATENT COOPERATION TREATY

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

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Date of mailing (day/month/year) 02 March 2001 (02.03.01)	
International application No. PCT/SI00/00017	**Applicant's or agent's file reference** 022-P04PC/00
International filing date (day/month/year) 12 June 2000 (12.06.00)	**Priority date** (day/month/year) 15 June 1999 (15.06.99)
Applicant PIRŠ, anez et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

21 December 2000 (21.12.00)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was [ ] was not made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

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Annex to Form PCT/ISA/206

COMMUNICATION RELATING TO THE RESULTS OF THE PARTIAL INTERNATIONAL SEARCH

International Application No

P[illegible]SI 00/00017

1. The present communication is an Annex to the invitation to pay additional fees (Form PCT/ISA/206). It shows the results of the international search established on the parts of the international application which relate to the invention first mentioned in claims Nos.:

1-5

2. This communication is not the international search report which will be established according to Article 18 and Rule 43.

3. If the applicant does not pay any additional search fees, the information appearing in this communication will be considered as the result of the international search and will be included as such in the international search report.

4. If the applicant pays additional fees, the international search report will contain both the information appearing in this communication and the results of the international search on other parts of the international application for which such fees will have been paid.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 794 201 A (NIPPON CATALYTIC CHEM IND) 10 September 1997 (1997-09-10) page 16, line 36 - line 39	1
A	WO 96 10770 A (ROCKWELL INTERNATIONAL CORP ;CHUNG YOUNG J (US); LI ZILI (US); RYA) 11 April 1996 (1996-04-11) page 18, line 4 - line 31 page 19 -page 22 page 23, line 1 - line 11	1-5
A	US 4 983 335 A (INOUE TAKAO ET AL) 8 January 1991 (1991-01-08) the whole document	1-5
A	US 5 798 808 A (VAN HAAREN JOHANNES A M M ET AL) 25 August 1998 (1998-08-25) column 3, line 62 - line 67 column 4, line 1 - line 9	1-5
A	US 5 646 703 A (ARAKAWA KOHEI ET AL) 8 July 1997 (1997-07-08) cited in the application abstract; figures	1-5
A	US 5 245 456 A (NAGATSUKA TATSUKI ET AL) 14 September 1993 (1993-09-14) cited in the application abstract; figures	1-5

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

2

International Application No
P[redacted]I 00/00017

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5 480 964 A (CHENG STEPHEN Z D ET AL) 2 January 1996 (1996-01-02) cited in the application abstract; figures	1-5
A	US 5 298 199 A (CLERC JEAN F ET AL) 29 March 1994 (1994-03-29) cited in the application abstract; figures	1-5
A	US 5 178 710 A (HIKMET RIFAT A M ET AL) 12 January 1993 (1993-01-12) abstract; figures	1-5
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2

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			JP	9151218	A	10-06-1997
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PATENT COOPERATION TREATY

PCT

REC'D 23 OCT 2001

WIPO PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference 022-P04PC/00	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/SI00/00017	International filing date *(day/month/year)* 12/06/2000	Priority date *(day/month/year)* 15/06/1999
International Patent Classification (IPC) or national classification and IPC G02F1/13363		
Applicant INSTITUT "JOZEF STEFAN" et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 11 sheets.

3. This report contains indications relating to the following items:

   I ☒ Basis of the report
   II ☐ Priority
   III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   IV ☒ Lack of unity of invention
   V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
   VI ☐ Certain documents cited
   VII ☐ Certain defects in the international application
   VIII ☒ Certain observations on the international application

Date of submission of the demand 21/12/2000	Date of completion of this report 19.10.2001
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized officer Ward, S Telephone No. +31 70 340 3547

Form PCT/IPEA/409 (cover sheet) (January 1994)

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, pages:

1,2,4,5,9-23	as originally filed			
3,6,7,7a,8,8a	as received on	02/10/2001	with letter of	02/10/2001

Claims, No.:

1-6	as received on	02/10/2001	with letter of	02/10/2001

Drawings, sheets:

2/2	as originally filed			
1/2	as received on	14/12/2000	with letter of	14/12/2000

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
- ☐ the language of publication of the international application (under Rule 48.3(b)).
- ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:
   ☐ the claims, Nos.:
   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

   ☐ restricted the claims.

   ☐ paid additional fees.

   ☐ paid additional fees under protest.

   ☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☒ complied with.

   ☐ not complied with for the following reasons:

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☒ all parts.

   ☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-6
	No:	Claims	
Inventive step (IS)	Yes:	Claims	2
	No:	Claims	1,3-6
Industrial applicability (IA)	Yes:	Claims	1-6
	No:	Claims	

2. Citations and explanations
   see separate sheet

Re Item V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Reference is made to the following documents cited in the International Search Report:

D1: EP0794201 A

D2: US5528400 A

D3: EP 0428213 A

D4: US4983335 A

2.1 Claim 1 of the present application does not involve an inventive step (Article 33(3) PCT) for the following reasons: The document D1 discloses (see page 16, lines 36-39) a method for producing a transparent polymer plate comprising pouring a monomer mixture between two rigid surfaces (glass plates) separated by soft (i.e. deformable) spacers (sections of a soft vinyl tube), heating said layer to a temperature (55°C) which is lower than the glass phase transition temperature (137°C) and polymerising while said monomer remains in contact with the plates. It is implicit to the skilled person (see PCT International Preliminary Examination Guidelines IV-7.2) that the layer will be subsequently allowed to cool to room temperature.

2.2 Since the term "intensive" has no limiting effect, and may therefore be ignored, for the reasons set out in paragraphs 6.1 and 6.2, below, the process feature which differentiates claim 1 from document D1 is that the polymerisation of the layer is activated by UV light. However, the use of UV light to activate polymerisation is commonly known in the art, a wide range of intensities being used, depending on circumstances. The skilled person seeking a means to activate polymerisation of the monomer mixture would routinely consider this possibility, which does not therefore involve an inventive step.

2.3 Other differences between claim 1 and D1 relate not to additional process features, but to the consequences or results of the process features already mentioned. It has been shown that the skilled person would routinely consider the process of claim 1, and hence would presumably arrive at the same results. Thus these features place no further limitation on claim 1 which consequently lacks inventive step in the sense of Article 33(3) PCT.

3.1 Claim 2 of the present application appears to satisfy the requirements of Articles 33(2) and 33(3) PCT for the following reasons: The document D1 is regarded as being the closest prior art and discloses the features mentioned in paragraph 2.1 above. The process features which distinguish claim 2 from D1 are that of
-providing hard spacers between the rigid surfaces,
-activating polymerization of the layer by UV light in a first stage when the thickness of te layer is determined by the hard spacers so that the polymerisation proceeds only to a level at which an increased viscosity stabilizes the thickness of the layer allowing the hard spacers to be removed,
-activating polymerization of the layer by intensive UV light in a second stage while in contact with said rigid substrates until said layer is fully cured.

3.2 The problem to be solved by may be regarded as providing a process for producing a birefringent layer which enables easier removal of the spacers. In D1 the spacers are present during the entire polymerisation process, resulting in adhesion of the spacers to the cured polymer making removal of the spacers difficult. In the process of claim 2, the spacers are removed after a first polymerisation stage while the layer is a partially polymerised viscous fluid, thus making their removal easier. The second polymerisation stage takes place with the spacers removed, but with the layer still in contact with the rigid substrates, thus providing the required mechanical strains within the plane.

3.3 Such a solution is not disclosed or suggested in document D1. Document D4 (see column 5, lines 16-56) discloses a method for forming a plastic optical element comprising pouring a photopolymerisable liquid monomer into a mould, precuring the monomer with UV light so that it is not completely cured, removing the article from the mould and completing the polymerisation by and post-curing with UV light. The purpose of completely removing the article from the mould before the final polymerisation is to reduce internal strains within the article. Document D4 contains no suggestion to remove only part of the mould (i.e. the spacers) to thereby reduce strain only in the direction perpendicular to the layer, while retaining other parts of the mould (i.e. the rigid plates) during the final polymerisation to thereby maximize the strains in the plane of the layer. Thus, having regard to the prior art, it would not be obvious for the skilled person to arrive at the solution of claim 2, and hence claim 2 satisfies the requirements of Articles 33(3) PCT.

4.1 Claim 3 is drafted as an independent claim seeking protection for the use of a product, the product itself being defined by a manufacturing process. Such a formulation appears to be unnecessarily complex and makes it difficult for the reader to construe the scope of the claim (Article 6 PCT). In addition, this formulation does not appear consistent with the other features of the claim which relate to processes (e.g."is polymerised in such a manner that") or device features of the LC optical light shutter. It appears that the subject-matter for which protection is sought is in fact a *process for manufacturing an LC optical light shutter*, and claim 3 has therefore been construed in this manner. Furthermore, the significance of the phrase "manufactured according to claims 1 or 2" is obscured by its inclusion in the above mentioned formulation. It appears that what is intended is that the processes according to claims 1 or 2 should be included as an integral part of the process for manufacturing an LC optical light shutter. Claim 3 has therefore been construed in this manner, by considering the phrase "wherein the optical compensation layer is polymerised in such a manner that" to be replaced by the process step: "manufacturing the optical compensation layer according to claims 1 or 2 in such a manner that", with the "rigid substrate surfaces" of claims 1 or 2 being identified with the appropriate surfaces of the LC light shutter of claim 3.

4.2 Since claim 3, as construed according to paragraph 4.1, depends on claim 1 (shown above not to involve an inventive step), claim 3 is not considered to involve an inventive step in the sense of Article 33(3) PCT for the following reasons: The LCD device features of claim 3 are disclosed in D2 (or from common general knowledge in the art). The feature that the polymer layer "simultaneously performs the function of combining the subcomponents of the LC shutter into a functional unity while at the same time ensuring angular compensation of the LC optical light shutter" means that the polymer layer is a birefringent adhesive. However, the use of birefringent adhesives is well known in the art, and would be routinely considered by the skilled person (e.g. to simplify construction by reducing the number of layers). For purposes of illustration, an example of an optical device employing a layer of polymeric birefringent adhesive is given in document D3 (see abstract). Inclusion of the feature that the polymer layer should be manufactured according to claim 1 merely adds an alternative manufacturing method shown to be obvious in paragraphs 2.1 - 2.3, above. Thus claim 3 appears to be a juxtaposition of known or obvious features which does not involve an inventive step (Article 33(3) PCT).

5. Dependent claims 4-6 appear to add device features which are known in the field of liquid crystal displays, and hence do not involve an inventive step (Article 33(3) PCT).

<u>Re Item VIII</u>

Certain observations on the international application

6.1 The relative term "intensive" has no precisely defined meaning (see PCT International Preliminary Examination Guidelines III-4.5), and since claim 1 offers no definition of the term, there is nothing to prevent those intensities commonly used in the art from being referred to as "intensive".

6.2 The only disclosure in the description which appears relate to this feature is that a 300-1000W UVA light source is used (see e.g. page 13, paragraph 2). However, neither the dimensions of the source or the layer, nor the distance between the source and the layer are given, and it is therefore impossible to infer anything about the light intensities used. Furthermore, the light source powers mentioned would appear to fall within a range commonly used in the art for such purposes. For these reasons it is considered that the term "intensive" as used in claim 1 has no limiting effect, and that no more precise definition of the term is disclosed in the description.

and Rockwell, USA (WO96/1077

94, p 923-926; US 5,344,916; US 5,580,950; US 5,480,964). They disclosed that by means of centrifugal deposition of a thin layer of preimidized polyimides the long molecular segments were preferably oriented in the plane of the deposited layer, resulting in strong negatively birefringent properties of such layers, which represent an inexpensive and technically relatively simple solution of the above described technical problem.

as well as Philips (US 5,798,808)

By all means, there also merit attention several technical solutions developed for computer terminals (#3) in companies, such as Nito Denko (Fujimura *et al.* SID Digest 91, p 739, SID Digest 92, p 397-400; US 5,245,456, ...), Sumitomo (Nakamura *et al.* US 5,061,042, ...) and (#4) Fuji Film (Mori *et al.*, US 5,559,618; Mori *et al.*, Display and Imaging 5, p 1 (96); Kamata *et al.*, US 5,646,703; Mori *et al.* US 5,583,679) and Akzo Nobel (Picken *et al.* US 5,382,648; US 5,525,265,...). The companies Nito and Sumitomo (#3) developed a multi-layer compensation film based on a one-dimensional deformation or stretching respectively; the Fuji company (#4) developed a polymeric discotic liquid crystal compensation sheet, the optical compensation properties of which could be altered with respect to the viewing/observation angle of the computer monitor; the Akzo Nobel company (#4) developed polymeric holesteric liquid crystal compensation films on various polymers, which were ideally adapted for the angular compensation of STN computer monitors. All above-mentioned solutions are primarily intended for the angular compensation of the contrast in multi-plexially monitored LC monitors, in which the homeotropic orientation of the LC molecules in the selected pixel is not entirely feasible. For this reason, such solutions are neither technically nor economically appropriate for the above-mentioned technical problem, that is the angular compensation of LC optical light shutters, operating on the principle of electrically controlled birefringence, in a the state with highly homeotropically aligned LC molecules.

Uchida, Stanley (#1) and Nito as well as Sumitomo Chemicals (#3) employ the principle of two- or one-dimensional stretching of a preformed, that is a polymerized thermoplastic polymeric sheet. On the other hand, Harris and Cheng and Hughes (#2) utilize the method of alignment of long molecular segments by means of a specific method of deposition of a prepolymerized polymer solution, such as the deposition of a preimidized polyimide on a rotating plate.

selection of functional groups within the segment of polyimide, controlling the rigidity of polyimide backbone chain rigidity and symmetry

The present invention is based on the utilization of the volume contraction of the polymer during the very polymerization process, so that the monomer layer is during the polymerization in contact with the surface of at least one rigid flat plate, or is preferably sandwiched between two layers of thermally and mechanically stable, rigid materials, for example glass. In such a manner, strains are generated in the material in the plane, determined by the rigid boundary surfaces, and causing the corresponding deformation of otherwise isotropic macromolecules. Since this deformation of the macromolecules is effected during the polymerization process, the cross-polymerization permanently freezes the molecules in their deformed state, which is of the utmost importance for the long-term and thermal stability of the birefringent films, manufactured in such a manner. The term »freezes« should be interpreted in the sense of »hardens« or »becomes rigid« respectively. The very deformation of the macromolecules effected with cross-polymerization, endows the present invention with substantional advantages in comparison with hitherto known methods of stretching preformed that is polymerized polymeric sheets. The latter has been achieved by hitherto known processes either by means of a direct, more or less one-dimensional mechanical stretching, of the type utilized in the above mentioned technical solution #3 Group (Nitto, Sumitomo,...), or by means of a homogeneous, two-dimensional stretching of the thermoplastic polymeric sheet in the vicinity of the glass phase transition of the employed polymer, which is characteristic for the #1 Group of the above itemized known technical solutions – Uchida, Stanley,.... The claimed process does not

require technically sophisticated equipment for the controlled mechanical stretching. It enables mass production, and furthermore, may be adapted in such a manner, that the obtained negatively birefringent polymer layer exerts simultaneously a bonding action, that is the adhesion and the optical contact between the LCD cell, and the polarizing filter.

The present invention enables, in comparison with the technical solutions #2 a substantially reduced deformation of the molecules, thus requiring thicker layers. The manufacturing process is, however, less expensive, more flexible and enables a significantly broader choice of the materials, as well as an improved precision and reproducibility. An important advantage is also the possible adaptation of the manufacturing process, enabling the simultaneous adjustment of the thickness of the compensating polymeric layer to the individual LCD optical shutters, that is the adjustment as to the thickness and birefringence of the liquid crystal layer, the chosen polarizer, etc. This is not feasible in any of the three prior art processes, which require either an extraordinary exacting one- or multi-dimensional stretching (technical solutions #1 and #3), or an extraordinary sophisticated method for the deposition of the compensating layer (technical solutions #2). Feasible is only the mass production of the compensation sheet exhibiting a determined selected retardation value, which is, however, not necessarily optimal for the selected configuration of the LCD optical shutter. The characteristics of the selected configuration are influenced primarily by the thickness and the refractive index of the liquid crystal layer, the selected polarizers, etc.

INSERT PAGE 7a

The present solution is completely different from the technical solutions #4 Group (Fuji, Akzo-Nobel,...). The latter are indeed of high technical quality, the methods are, however, highly sophisticated and expensive. A mass production of a compensation layer with exactly defined characteristics is involved, which in principle impedes the adjustment to the specific characteristics of the individual LCD shutters. At the same time it has to be emphasised that such materials cannot be simultaneously utilized for the

It is true that the solutions #2 also typically use UV activated polymerization process just as is the case with the proposed process. Intense UV light curing must also result in some mechanical strain being generated within the birefringent polyimide layer. However as the effective birefringence, obtained by the selection of functional groups within the segments of the polyimide, which control the rigidity of polyimide backbone chain rigidity and symmetry is more than an order of magnitude bigger than is the case in the proposed technical solution. Therefore the thickness of the birefringent compensation layer, according to the solutions #2, has to be an order of magnitude smaller than in the case of the proposed solution. So the strain inducing UV activated polymerization process does not contribute to the overall birefringence of the compensating layers, manufactured according to the solutions #2. In view of this, the authors of the "solutions #2" do not use and never mention that the strain inducing UV activated polymerization could contribute to the birefringence of the compensating layers, manufactured according to the solutions #2.

bonding of the individual subcomponents of the LCD shutter into a functional unity.

In comparison with hitherto known technical solutions, based on the utilization of several LC cells (#5), the claimed invention enables a significantly less expensive and simpler application of the present process. The employment of each supplementary LC cell renders in fact the product significantly more expensive; furthermore, other important optical characteristics, such as light scattering, are deteriorated.

INSERT PAGE -8a-

The object of this invention is a process for manufacturing a polymeric optical compensation layer for LCD optical shutters, and the corresponding construction of such a shutter. The process ought to enable the manufacture of an optically negatively birefringent compensation layer, based on the controlled, spontaneous deformation of the polymeric macromolecules during the formation of the polymeric layer. The deformation of the polymeric macromolecules should result from the volume shrinkage of the polymer volume during the polymerization process, if the polymer layer is during the polymerization continually in contact with at least one rigid plate surface. Preferably, however, it is sandwiched between two rigid surfaces, under the provision, that the shrinkage of the polymer is unrestrained in the direction perpendicular to the surface plane. The expression "unrestrained" means, that it is in fact unrestrained, or that the mechanical strains in the direction perpendicular to the surface plane, are significantly reduced in comparison with the strains in the layer plane. The optically birefringent polymer compensation layer, manufactured in accordance with the present invention, ought to enable an easy adjustment to the specific characteristics of the individual LCD optical shutters, by means of adjusting the thickness of the layer *per se*, and the polymerization conditions.

In addition to the compensation of the angular dependence of the optical characteristics (light attenuation, ...) of the LCD optical shutter, the

Finally one also has to mention the technical solutions, which are not directly related to the problem of the angular compensation of the LCD light shutters, but are also dealing with processes or materials, similar to some extent to the proposed technical solution. In view of this one has to mention the EP patent application EP 0794 201 A1, in which the authors are using soft spacers in the preparation of the foils of heat resistant resin, with high optical transparency. At the first glance the preparation process of the plastic foils looks somewhat similar (use of soft spacers). However without enhanced speed of the polymerization, obtained by intense UV light exposure of the UV-sensitive polymers, as used in the proposed technical solution, the birefringent properties of the foils, obtained according to the process, described in the patent EP 0794 201 A1, would be at least an order of magnitude smaller and therefore practically useless for solving the technical problem of the angular compensation of the LCD light shutters. Furthermore the authors of this patent do not try to address at all the technical problem of manufacturing the polymer foils, having controlled birefringence, necessary for the angular compensation of the LCD light shutters. Since the proposed technical solution finally results in an optical sealant with controlled anisotropic properties, one has to mention also the patent application of Philips (EP 0 428 213 A1). Also in this case the birefringent adhesive layer, as proposed by the authors, cannot have the negative birefringence properties perpendicular to the layer surface. Furthermore the concept for obtaining the birefringence properties is based on the use of LC polymers rather than on strain-inducing polymerization process, as is the case in the proposed technical solution.

PATENT CLAIMS

1. A process for the manufacturing of an optical compensation polymer layer for a LC optical light shutter, which is optically negatively birefringent and has the optical axis perpendicular to its surface, comprising the following steps:
   - pouring a monomer or pre-polymer mass as a layer (3) uniformly over a rigid substrate surface or
   - pouring a monomer or pre-polymer mass as a layer (3) between two rigid substrate surfaces, separated uniformly by soft spacers, which are deformed under pressure, generated in the layer (3) as a result of shrinkage during polymerization,
   - preheating said layer (3) to an elevated temperature, which is lower than the polymer glass phase transition temperature,
   - activating the polymerization of said layer (3) by intensive UV light while in contact with said at least one rigid substrate surface until said layer (3) is fully cured, so that mechanical strains result from the shrinking of the polymer during the polymerization process, the mechanical strains in the direction perpendicular to the surface being significantly smaller than within the plane of the layer (3), and
   - finally cooling down said layer (3) to room temperature.

2. A process for the manufacturing of an optical compensation polymer layer for a LC optical light shutter, which is optically negatively birefringent and has the optical axis perpendicular to its surface, comprising the following steps:
   - pouring a monomer or pre-polymer mass as a layer (3) between two rigid substrate surfaces separated by hard spacers (5),
   - activating polymerization of said layer (3) by UV-light (6) in a first stage, when the thickness of the layer (3) is determined by the hard spacers (5), so that the polymerization proceeds only to a level, at which an increased viscosity stabilizes the thickness of the layer (3) allowing the hard spacers (5) to be removed,

- preheating said partially polymerized layer (3) to an elevated temperature, which is lower than the polymer glass phase transition temperature,
- activating polymerization of said layer (3) by intensive UV light in a second stage while in contact with said rigid substrate surfaces until said layer (3) is fully cured, so that mechanical strains result from the shrinking of the polymer during the polymerization process, the mechanical strains in the direction perpendicular to the surface being significantly smaller than within the plane of the layer (3), and
- finally cooling down said layer (3) to room temperature.

3. The use of an optical compensation polymer layer (3) having negative birefringence manufactured according to claims 1 or 2 for angular compensation of an LC optical light shutter, comprising as subcomponents a LC cell (13), two crossed polarizers (12, 15), an outside protective IR/UV filter (11) and an inside protective glass plate (2) wherein at least one of the polarizers (12, 15) is directly laminated by means of a standard adhesive (17) to an inner surface of the inside protective glass plate (2) instead of directly to the LC cell (13), and the optical compensation polymer layer (3) is arranged between at least one of the polarizers (12,15) and the LC cell (13), and wherein the optical compensation polymer layer (3) is polymerized in such a manner that it simultaneously performs the function of combining the subcomponents of the LC optical light shutter into a functional unity, while at the same time ensuring an angular compensation of the LC optical light shutter in a state, in which the molecules of the LC cell (13) are homeotropically oriented with respect to boundary surfaces of the LC cell (13).

4. The use according to claim 3, wherein a rigid, preferably glass plate (18) separates one of the polarizers (15) from the optical compensation polymer layer (3), said optical compensation polymer layer (3) being sandwiched between the LC cell (13) and the rigid glass plate (18), the two crossed polarizers (12,15) being laminated by means of a standard optically isotropic contact adhesive (17) on each surface of such assembly, which is laminated between the inside protective glass plate (2) and the IR/UV filter (11) by means of a further standard optically isotropic contact adhesive (17).

5. The use according to claim 3, wherein an additional optically positively-birefringent polymer layer (19) is arranged between one of the polarizers (12, 15) and the LC cell (13), the thickness of said additional polymer layer (19) corresponding to the requirement for a $\lambda/4$ plate for a specified spectral domain of the LC optical light shutter, with the slow axis of said $\lambda/4$ plate being parallel to a polarization axis of the polarizer (15), wherein the thickness (L) of the optical compensation polymer layer (3) having negative birefringence is such that together with a difference between refractive indices for ordinary and extraordinary rays (Δn) results in a difference of the optical paths for the ordinary and the extraordinary rays (Δn_L x L), which is smaller than the difference of the optical paths for the ordinary and the extraordinary rays in the LC cell with homeotropically oriented molecules (Δn_{LC} x d_{LC}), so that with the optical compensation polymer layer (3) with negative birefringence and optically negative birefringence of the polarizers (12, 15), an optically uncompensated part of a LC layer in the LC cell (13) behaves as an optically positively birefringent plate, the optical axis of which is perpendicular to the axis of the $\lambda/4$ plate (19), while this uncompensated difference of the optical paths is such that together with the $\lambda/4$ plate (19) it ensures the angular compensation of the crossed polarizers of the LC optical light shutter.

6. The use according to claim 3, wherein an additional optically negatively-birefringent polymer layer (19) is arranged between one of the polarizers (12, 15) and the LC cell (13), the thickness of said additional polymer layer (19) corresponding to the requirement for a $\lambda/4$ plate for a specified spectral domain of the LC optical light shutter, with the slow axis of said $\lambda/4$ plate being parallel to a polarization axis of the polarizer (15), wherein a thickness (L) of the optical compensation polymer layer (3) having negative birefringence is such that together with a difference between refractive indices of optical paths for ordinary and extraordinary rays (Δn) results in a difference of the optical paths for the ordinary and the extraordinary rays (Δn_L x L), which is greater than a difference of the optical paths for the ordinary and the extraordinary rays in the LC cell (13) with homeotropically oriented molecules (Δn_{LC} x d_{LC}), so that with the optical compensation polymer layer (3) having negative birefringence (3) and optically

negative birefringence of the polarizers (12, 15), an optically uncompensated part of a LC layer in the LC cell (13) behaves as an optically negatively birefringent plate, the optical axis of which is perpendicular to the axis of the $\lambda/4$ plate (19), while this uncompensated difference of the optical paths is such that together with the $\lambda/4$ plate (19) it ensures the angular compensation of the crossed polarizers (12,15) of the LC optical light shutter.

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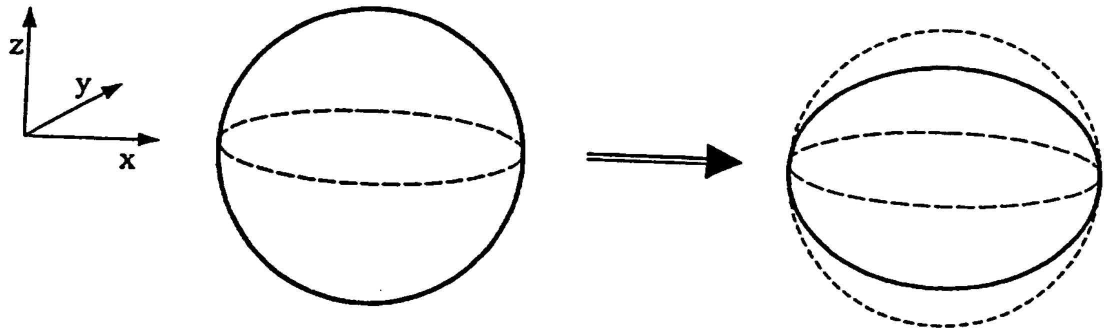

FIG. 1

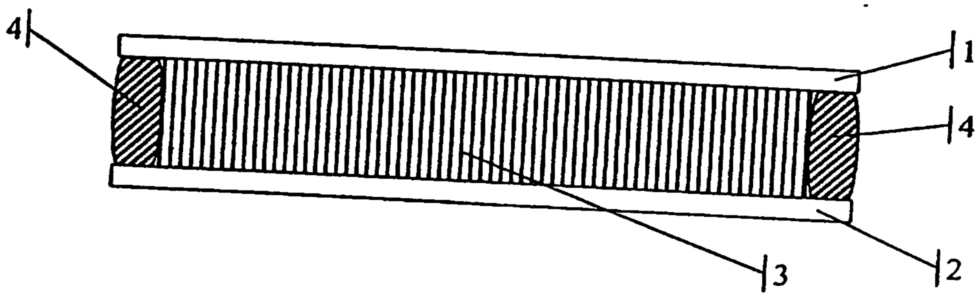

FIG. 2

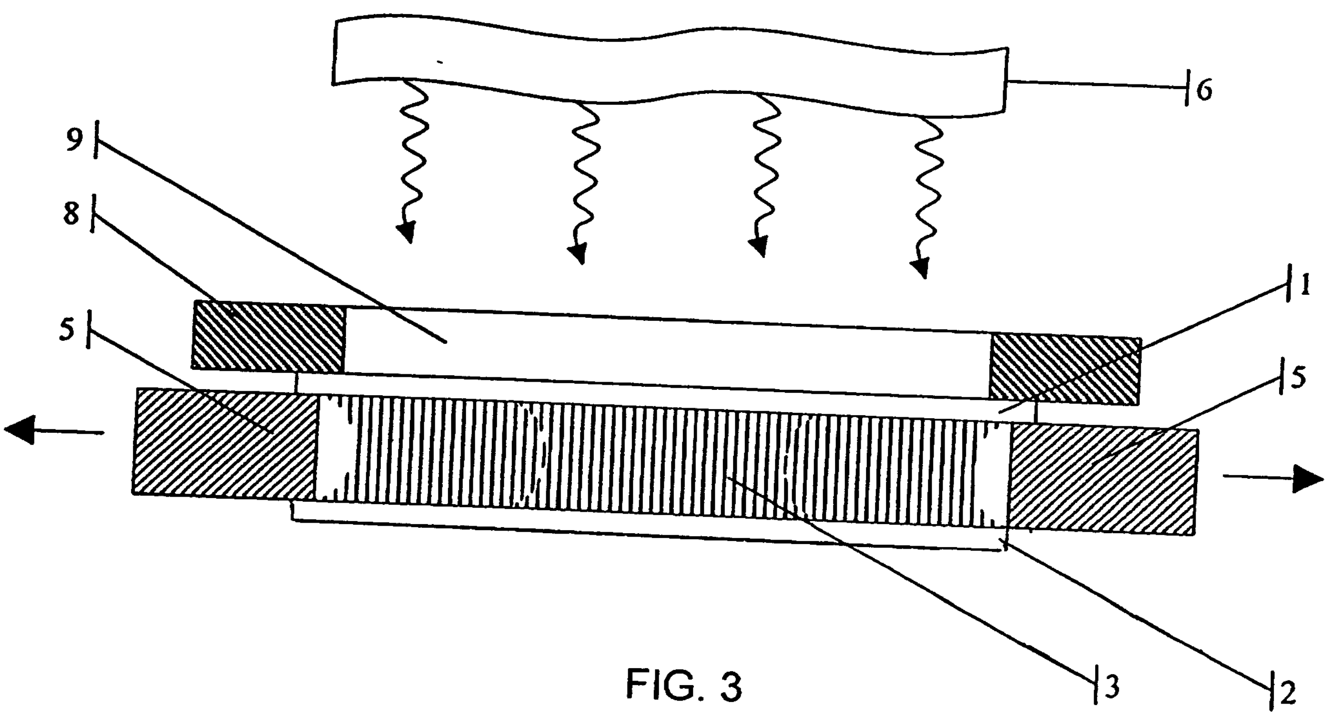

FIG. 3